TECHNICAL MEMORANDUM
OU/AEC 98-16TM00078/2-1

DEVELOPMENT OF PROVISIONAL FLIGHT INSPECTION CRITERIA FOR WIDE AREA AUGMENTATION SYSTEM (WAAS) APPROACH PROCEDURES

Provisional flight-inspection criteria are provided for Wide Area Augmentation System (WAAS) precision approach procedures.

by

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September 1998

Federal Aviation Administration
800 Independence Avenue, SW
Washington DC, 20591

Contract DTFA01-97-C-00078
Technical Task Directive - 2

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I. INTRODUCTION

Technical Task 2.0 to FAA Contract DTFA01-97-C-00078 entitled, “Flight Inspection Criteria for Satellite-Based Navigation Systems”, supports the development and verification of flight inspection criteria for satellite-based navigation systems. These criteria are intended to provide a suitable means for implementation and integration of satellite-based navigation systems into the National Airspace System (NAS).

In order to facilitate the integration of satellite-based navigation systems into the NAS, standards must be developed based on specific operational requirements and system architectures. The objective of these standards is to detail, in terms of system-architecture-specific parameters, the minimum performance required to support a given procedure. The standards development process includes the generation of flight inspection criteria. These criteria address the specific system parameters to be assessed and the assessment methodology required to ensure that the installed-system performance is suitable for supporting the intended procedure(s). Such flight inspection criteria must be developed and verified to enable the implementation of the Wide Area Augmentation System (WAAS).

The following specific work items are intended to be performed under this technical task directive:

Parameter Identification - Develop a list of specific system parameters that will be recorded during flight inspection of WAAS procedures.

Assessment Methodology - Develop methodologies for assessing the data collected for the system parameters identified.

Criteria Development - Provide technical support for the development of WAAS flight inspection material for inclusion in the appropriate FAA Orders.

Verification - Through the use of FAA and Ohio University facilities and resources, verify the flight inspection criteria that have been developed. Through actual implementation, assess the technical merit of the specific parameters considered, data collection and assessment methodologies utilized, and any implementation issues that may arise during the actual application of the criteria.

This report describes the WAAS Precision Approach (PA) procedure and its components. A preliminary description of the parameters that must be recorded and the assessment methodology needed during flight inspection are described. Due to schedule constraints, this preliminary report does not provide an in-depth analysis of the criteria development. At the present time, this report provides insight into the WAAS flight inspection procedure from an analytical viewpoint. There were no attempts to verify the procedure via actual implementation of a WAAS airborne system. The Avionics Engineering Center feels strongly that verification of the WAAS Flight Inspection procedure must be performed.

II. OVERVIEW OF GPS/WAAS PROCEDURES AND FLIGHT-INSPECTION REQUIREMENTS

The development of the WAAS Flight Inspection criteria is based on the site-specific components of a WAAS instrument approach procedure. While the space and ground components of both GPS and WAAS affect the WAAS approach, the flight inspection procedure relies on the inherent monitoring of those systems to determine faults. The same philosophy applies to the WAAS/GPS receiver. The flight inspection procedure is not intended to provide an assessment of receiver performance as this matter is appraised during equipment certification. This philosophy does not exclude the recording of GPS and WAAS parameters. The parameters are needed to determine why an inspection run may have failed and for determining if there has been any local corruption or interference of the signal.

A. Overview of GPS/WAAS Procedures

1. **Basic "T"**

As illustrated in Figures 1 and 2, the GPS approach procedure uses the Basic "T" with the addition of a terminal arrival area (TAA). The Basic "T" is used for stand-alone GPS approaches (TSO C-129), WAAS, and LAAS approaches.

The Basic "T" aligns the final approach segment with the runway centerline. The Missed Approach Point (MAP) is at the runway threshold and the Final Approach Fix (FAF) is 5 nmi from the threshold. The Intermediate Fix (IF) is 5 nmi beyond the FAF, along the runway centerline. There are two Initial Approach Fixes (IAF) located 4 or 5 nmi either side of the IF. The IAFs are typically located 90 degrees with respect to the runway centerline. The GPS procedure is designed to eliminate the procedure turn. If a course reversal is required, a holding pattern will be specified in lieu of a procedure turn.

The TAA (shown in Figure 2) provides the transition from enroute airspace to the GPS approach. Step-down altitudes and transitions are provided for all approach paths except for areas where terrain clearance or ATC limitations are required. The TAA is typically defined for a 30 nmi arc from the IAF. There are three areas in the TAA. Aircraft transitioning to the Basic "T" from a heading that is within 90 degrees of the final approach course are directed to the IAF/IF. The IAF/IF is located at the IF on the extended runway centerline. Aircraft that are approaching the GPS procedure with a bearing greater than 90 degrees to the final approach course are directed to one of the IAFs. These aircraft are approaching the GPS procedure from the Left or Right Base.

To accommodate FMS and RNAV approach equipment, waypoints are designated as Fly-Over or Fly-By. Fly-By waypoints are used when the navigation system is allowed to transition from one segment to the next segment before passing the waypoint. This technique provides what is known as turn anticipation. Terrain and obstacle clearance must compensate for turn anticipation.

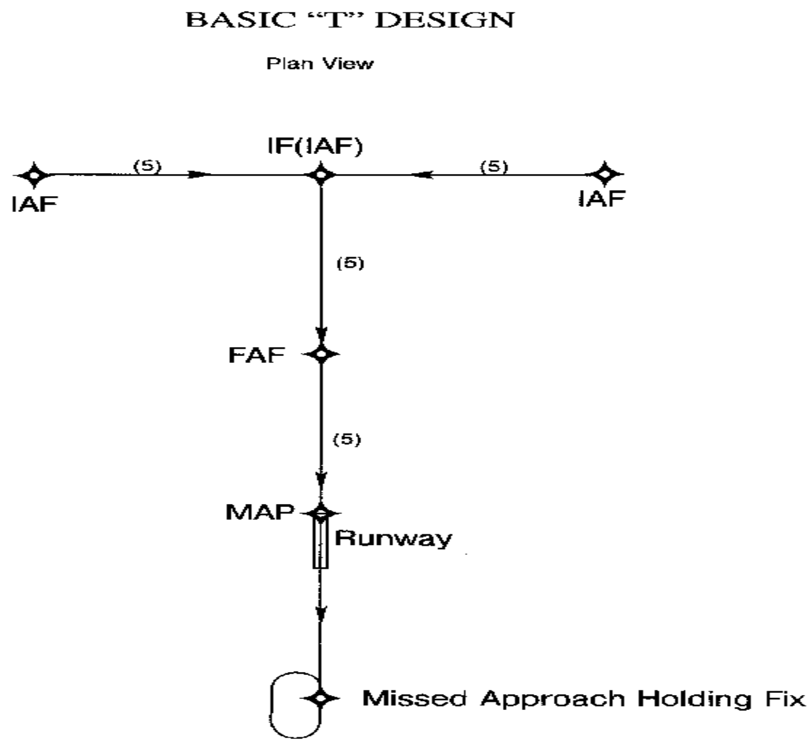

Figure 1. Basic "T" GPS Approach Procedure [1].

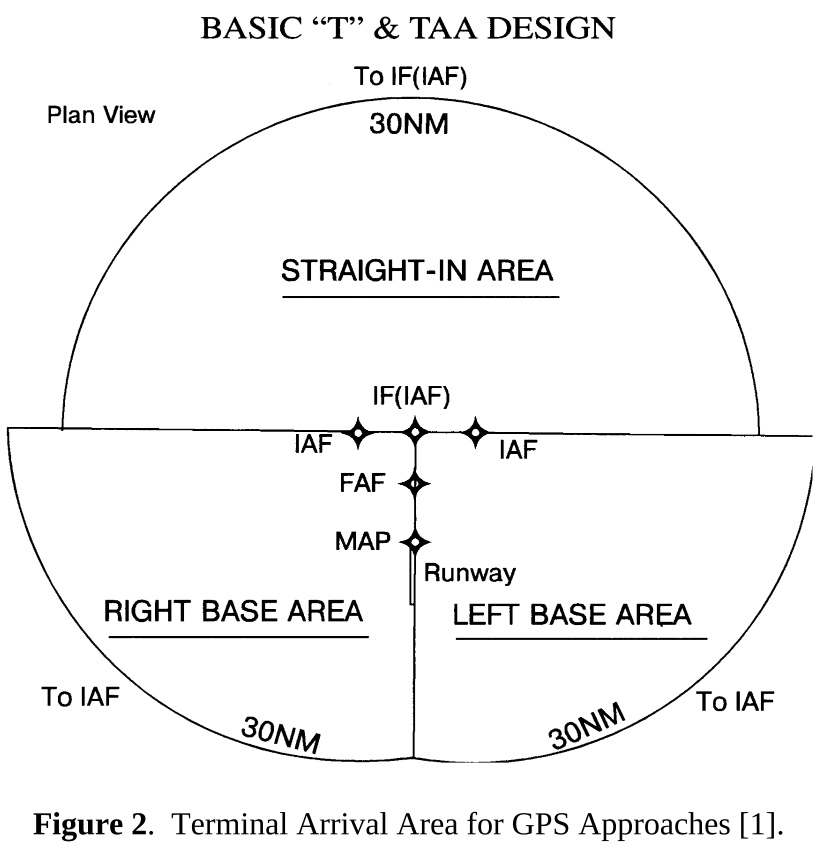

Figure 2. Terminal Arrival Area for GPS Approaches [1].

2. Non-Precision Approach (NPA)

A GPS NPA is defined for aircraft equipped with GPS receivers certified for non-precision approach (TSO C129 A1, B1, B3, C1, or C3) and WAAS/GPS receivers. The C129 receivers do not receive differential corrections and therefore are not sufficiently accurate for a precision approach. The WAAS/GPS receivers may use a NPA in two situations. First, the pilot may select a NPA. Second, system accuracy, availability, or integrity may inhibit a PA which causes the system to revert to a NPA.

A GPS NPA consists of sequenced waypoints from the initial approach waypoint (IAWP) to the Missed Approach Waypoint (MAWP). After the aircraft passes the FAWP, it is allowed to descend to the Minimum Descent Altitude (MDA). There is no vertical guidance for a NPA. During the commissioning Flight Inspection, all the Initial Approach Segments (IAS) and Missed Approach Segment (MAS) are flown at the procedural altitudes. An IAS may be evaluated when flying by the IAWP if it is a Fly-By waypoint for turn anticipation. The Final Approach Segment (FAS) is verified to be a straight line from the FAWP to the MAWP. The flight inspection procedure starts 3 nmi outside the first waypoint in a straight line with the FAWP and MAWP. This may be either an IWP or the FAWP. All the waypoints that are on this line are evaluated by flying over the waypoints. The FAS is flown to 100 feet below the published altitude (MDA) from the FAWP to the MAWP. Only the FAS is checked during periodic flight checks.

The procedure database is evaluated to verify the geodetic coordinates of each waypoint and the distance/bearing between waypoints. The acceptable tolerances for GPS C-129 procedures are defined for each segment. During the IAS/IS, the true bearing to the next WP must be within ± 2 degrees and the distance must be within ± 0.5 nmi. For the FAS, the bearing and distance to the next WP are ± 2 degrees and ± 0.3 nmi, respectively. The bearing and distance to the next WP on the Missed Approach Segment is ± 2 degrees and ± 0.5 nmi.

The Standard Instrument Approach Procedure (SIAP) is evaluated during the commissioning and periodic flight checks per 8200.1A, Section 214.3 [2]. The SIAP evaluation considers: flyability, cockpit workload, navigation chart data, runway markings and lighting, and navaid (GPS, ILS, VOR, etc.) support.

GPS system parameters are also collected during the flight inspection. There are no flight inspection requirements for these parameters. They provide analysis data if any GPS signal anomalies or interference are encountered. The GPS parameters and their expected values are shown in Table 1.

Table 1. GPS Parameters Collected During the Flight Inspection [2].

Parameter	Expected Value
HDOP	4.0 maximum
HFOM	835 ft./ 255 m.
Satellites tracked	4 minimum
CNR	30 dB/Hz minimum

The electromagnetic spectrum in the GPS L1 and L2 bands are monitored if RF interference is suspected. The frequencies to be monitored are in the range of 1200 to 1250 MHz and 1555 to 1595 MHz. The normal GPS signal strength is –130 to –123 dBm. Particular attention shall be given to harmonics on or within 20 MHz of GPS L1 (1575.42 MHz) and those on or within 10 MHz of GPS L2 (1227.6 MHz).

3. Precision Approach (PA)

The WAAS PA can be established via the Basic "T" Approach configuration presented in Figure 1 or via the Vector To Final (VTF) procedure. In the Basic "T", the Initial/Intermediate Approach Segments are similar for the WAAS and C-129 approach procedures. In the VTF procedure, the aircraft discontinues the initial/intermediate segments on the published approach and is vectored to an extended final approach segment. In both cases, the main difference between the PA and the NPA is the Final Approach Segment. The WAAS receiver has sufficient accuracy to support the vertical guidance required for the FAS.

The horizontal and vertical components of the Final Approach Segment (FAS) are calculated from waypoints associated with the runway environment as shown in Figure 3. The horizontal course is defined as an extended runway centerline using the Runway Datum Point (RDP) and the Flight Path Alignment Point (FPAP). A straight-in approach is currently defined for WAAS PA operations although the approach path may be offset from the runway centerline. This is accomplished by moving the RDP and/or FPAP to a point off the runway surface.

A linear path defined by the Datum Crossing Height (DCH) and the glidepath angle establish the vertical course. The glidepath angle is defined with respect to the local tangent plane of the WGS84 ellipsoid. The Glide Path Intercept Point (GPIP) is where the glidepath intersects the local tangent plane. The GPIP is not part of the FAS database, but is only included for reference.

The parameters defining the FAS are stored in the WAAS receiver database for each approach. The parameters stored in the FAS data block are airport identification, runway designation and position, procedure type, procedure name, and runway surveyed points. The procedure type is included for the development of advanced approach procedures such as curved approaches. Only straight-in approaches are currently defined.

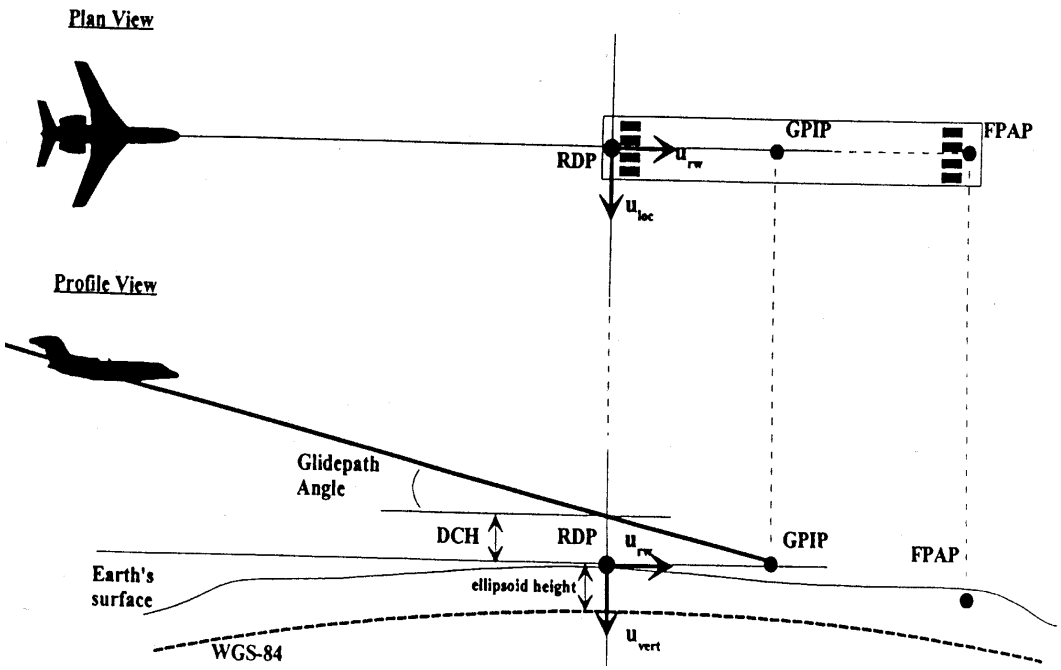

Figure 3. Final Approach Segment of WAAS Precision Approach [5].

B. General Inspection Requirements

WAAS DGPS Flight Inspection criteria outline the parameters and their respective tolerances which will define whether an approach is approved or not. Criteria used in this determination are listed below.

Waypoint Displacement Error (WPDE) – WPDE describes the positional error associated with a waypoint. WPDE can be caused by incorrect geographic coordinates or the resolution in which they are stored in the database.

Horizontal Protection Limits (HPL) / Vertical Protection Limits (VPL) – HPL/VPL are values calculated by the WAAS receiver. They denote the uncertainty associated with the 3-dimensional positional accuracy that is output by the receiver. HPL/VPL are affected by the number of GPS satellites, GPS satellite geometry (HDOP/VDOP), tropospheric delays, and airborne receiver accuracy. HPL/VPL are compared to the Horizontal Alert Limit/ Vertical Alert Limit (HAL/VAL). If either the HPL (VPL) exceeds the HAL (VAL), then the WAAS receiver must flag all or parts of the approach procedure.

Obstruction Clearance - All aircraft paths approved by the approach procedure must be free of obstacles and obstructions. This may include towers, buildings, and terrain. Obstruction clearance is initially determined by examining FAA and other government databases. During the Flight Inspection, obstacle clearance is determined by pilot observation.

Standard Instrument Approach Procedure (SIAP) - The instrument approach procedure must be checked for flyability, waypoint accuracy, obstructions, and interference. The entire SIAP is checked from Initial Approach Waypoints to the Missed Approach Holding Waypoint.

III. DEVELOPMENT OF WAAS PRECISION APPROACH FLIGHT INSPECTION CRITERIA

Four types of assessments should be accomplished during flight inspection of the published WAAS precision approach procedure. The first assessment validates the location of any way points or database information used to construct or execute the approach, e.g., FPAP, DCH, RDP, etc. The second assessment relates to documenting the flyability of the procedure, while the third assessment addresses the identification of RF interference. The fourth assessment verifies the obstruction environment surrounding the procedure.

Specifications for the WAAS signal-in-space and WAAS airborne equipment were reviewed to determine what system parameters need to be recorded and what analysis is required to complete these four assessments [3,5]. At this writing, it appears that flight inspection of WAAS precision approach procedures should include at least the following two maneuvers: flying the published approach procedure; and, performing below procedure runs.

Example flight inspection data plots (records) have been developed to aid the explanation of what system parameters need to be recorded and how these parameters can be analyzed to accomplish the four types of assessments mentioned above. Further, these example data plots are not intended to suggest any requirements or recommendations on the graphical format of the flight inspection record.

A. Approach Procedure Maneuver

The approach procedure maneuver involves flying the final approach segment of the published WAAS precision approach procedure. Since the horizontal and vertical course widths are not a function of the signal-in-space, the need to fly approach maneuvers at the horizontal and vertical course limits is not anticipated at this time.

Three of the four types of assessments are performed during the approach procedure maneuver. The three assessments are: validating the location of the waypoints; documenting the flyability of the procedure; and, identifying the presence of RF interference.

Figures 4 and 5 show example flight inspection records for the approach procedure maneuver. Each of these records is comprised of a header and seven data windows. One such record would be generated to assess horizontal performance (Figure 4) and one to assess vertical performance (Figure 5). The data content and analysis to be performed using these records is explained as follows.

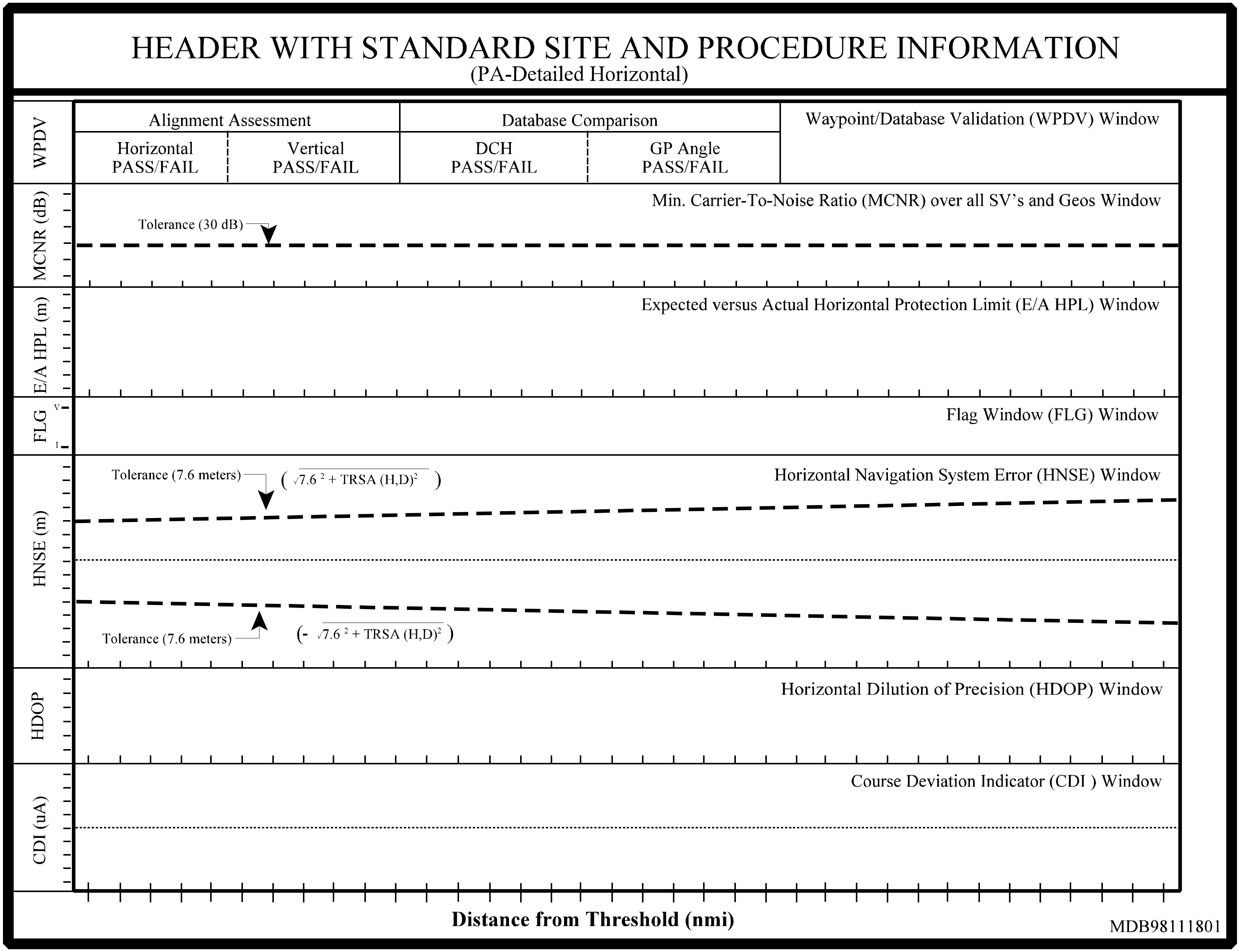

Figure 4. Example Record for the Approach Procedure Maneuver, Horizontal Performance, Detailed Format.

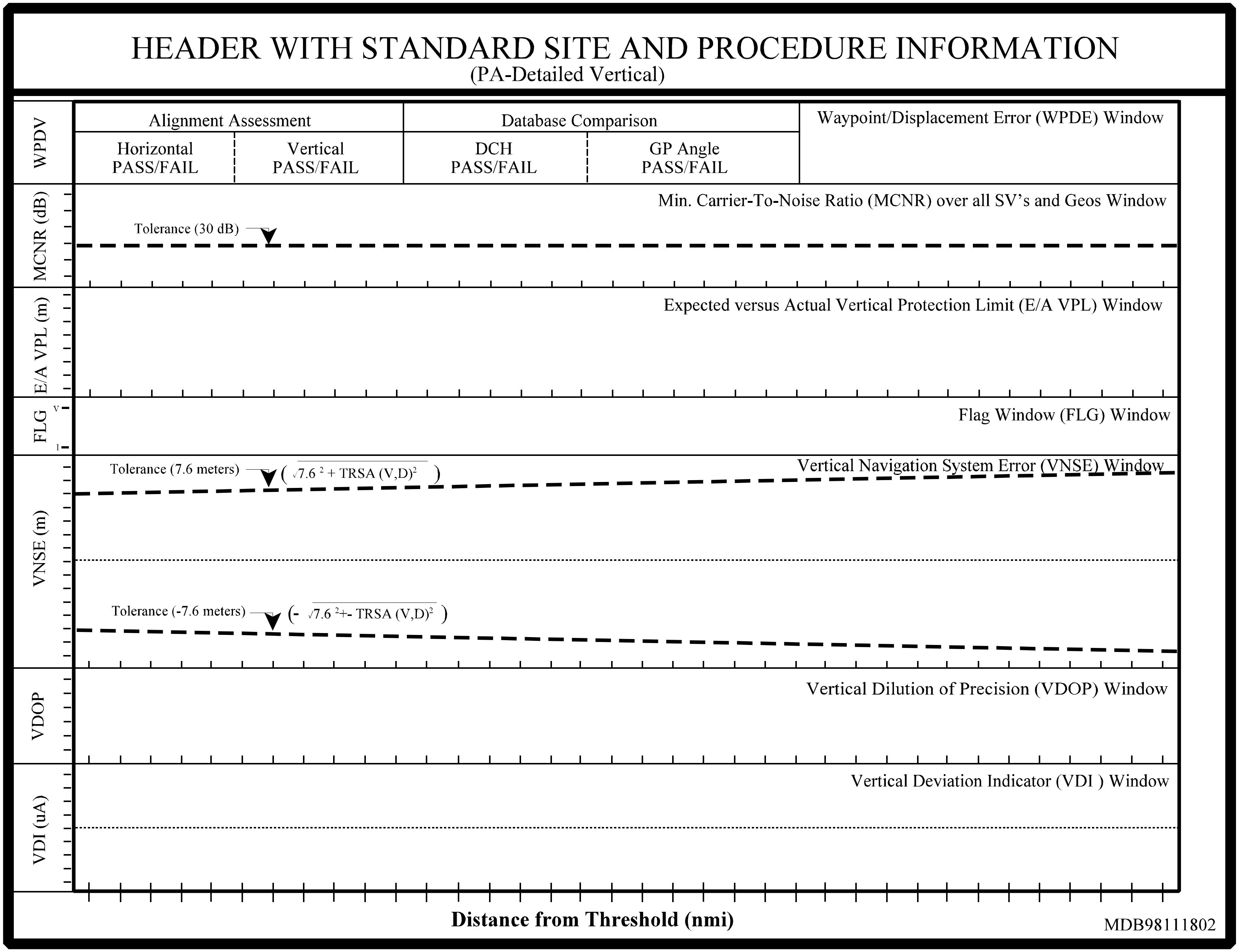

Figure 5. Example Record for the Approach Procedure Maneuver, Vertical Performance, Detailed Format.

Header Block: The header (Figure 4) should consist of the standard site and procedure information used by the FAA to document flight inspection of a precision approach procedure.

Waypoint / Database Validation: The top data window (vertical label WPDV in Figure 4) is used to present data for verifying the location of any waypoints and database information used to construct the approach procedure. The waypoint information is obtained from an on-board database that contains the approach procedure. Applicable standards [3, 5] do not provide practical requirements for measuring waypoint accuracy using an airborne platform given the tolerances that are required for waypoints in the runway region. Thus, an alternate method for verifying the location of the waypoint is required.

For Category I operations, there may not be any operational benefit gained by explicitly measuring waypoint displacement error (WPDE), since the effect of WPDE on the approach procedure may be assessed sufficiently when the procedure is flown by the flight inspection aircraft. A method for performing such an assessment, as well as verifying pertinent database information, is described in the following paragraphs.

The horizontal course is defined by the line containing both the RDP and the FPAP (Figure 3). The values for these parameters are obtained from a database containing the Final Approach Segment (FAS) Data Block [5]. Error in surveying or recording the values for these waypoints can result in a horizontal track that is rotated or/and offset from the desired track. Thus, the waypoint and database information can be verified by assessing the angular/linear alignment of the horizontal course. The assessment is performed by ensuring that the average horizontal course is within the NSE tolerance brackets, which are discussed in a subsequent paragraph. This assessment could be performed using a method similar to the one used for assessing the ILS localizer alignment [2]. The result of the assessment may be displayed as illustrated in Figure 4. The vertical course is defined by a DCH, glidepath angle, and RDP (Figure 3). The values for both the DCH and glidepath angle are obtained from a database containing the FAS Data Block [5]. Error in the values used for the DCH and/or error in the location of the RDP can result in an unacceptable threshold crossing height. Error in the value of glidepath angle will result in angular bias in the vertical course. Since the DCH and glidepath angle are specified values as opposed to values for surveyed locations, an independent comparison of these values should provide a sufficient assessment. In this case, the AFIS could serve as the independent reference for the correctness of the values obtained from the FAS Data Block. Given the resolution specified for these values in Reference 5 and assuming the AFIS would store these data with at least the same resolution, the DCH values should agree within 0.2 feet and the glidepath angle values should agree within 0.02°.

The RDP waypoint information may be verified by assessing the alignment of the vertical course. The assessment is performed by ensuring that the average vertical course is within the NSE tolerance brackets, which are discussed in a subsequent paragraph. This assessment could be performed using a method similar to the one used for assessing the ILS glide slope alignment [2]. The result of the assessment may be displayed as illustrated in Figure 4. The achieved DCH could be compared to the desired DCH (value in FAS Data Block); this assessment may be considered optional considering that the WAAS is intended to support NPA and Category I PA operations. Further analysis is required to determine if there would be any operational benefit obtained from performing such an assessment.

Minimum Carrier-to-Noise Window: The minimum carrier-to-noise (C/N) window (vertical label MCNR in Figure 4) is used to present data for assessing the presence of moderate RF interference and determining if it is of operational concern. That is, interference that is not strong enough to prevent acquiring or tracking of the satellites, but may degrade WAAS performance. Although C/N data should be collected for all tracked satellites, only the minimum ratio obtained for each measurement set is presented. The threshold to be used for this assessment should be developed based on the WAAS interference mask and WAAS receiver performance requirements [3], if practical. Though there was not sufficient time to accomplish a threshold analysis for this effort, operational experience indicates that the C/N ratio should be greater than 30 dB the vast majority of the time. Thus, a threshold of 30 dB is proposed as an initial value, until an analysis can be undertaken to determine a more suitable value.

Expected versus Actual Horizontal Protection Limit Window: The expected versus actual horizontal (or vertical) protection limit window (vertical label E/A H/VPL in Figure 4) is used to assess the presence of strong RF interference and to determine if it is of operational concern. That is, interference strong enough to prevent acquiring or tracking one or more satellites. Since the satellite is not tracked, C/N data can not be collected. Thus, there is a need for an additional assessment to alert the inspector of a problem. The expected horizontal (or vertical) protection limit is calculated based on WAAS provided information and the satellites that should be in view at that particular time and location. The actual horizontal protection level is calculated in a similar manner, except it is based on the satellites that were actually tracked. This approach assumes that the flight inspection receiver is required to track all satellites in view. The expected and actual protection limits should be nearly identical. Further work and operational experience will be required in order to establish a meaningful assessment limit(s).

Although it may be easier to determine the number of satellites tracked versus the number that should be tracked, such an approach is limited in terms of assessing the operational impact of the situation in a quantified manner.

Flag Window: The navigation flag window (vertical label Flg in Figure 4) is used to present the status of the horizontal (or vertical) navigation sensor flag. As with other precision approach aids, the flag is expected to remain valid during the entire approach.

Horizontal Navigation System Error Window: The horizontal (or vertical) navigation system error window (vertical label HNSE in Figure 4) is used to present the NSE data for assessment. For WAAS precision approach procedures, Table 3.2-2 in Reference 3 specifies a 7.6 meter tolerance for both vertical and horizontal NSE. Ideally, the measured NSE would be assessed against the 7.6 meter tolerance. However, this tolerance may be impractical to apply to the measured NSE data, particularly during the initial portion of the precision approach procedure, depending on the truth-reference system used. That is, for a truth system where the linear accuracy degrades as the distance from threshold increases, the truth-system measurement error may exceed the 7.6 meter tolerance at a distance from threshold that is less than 5 nautical miles. Therefore, the actual tolerance brackets to be used for the NSE assessment may depend on the characteristics of the truth-reference system. The following general equation provides a method for generating the magnitude of such tolerance brackets as a function of distance from threshold:

$$|T(H/V,D)| = \sqrt{7.6^2 + |TRSA(H/V,D)|^2}$$

Where:

T(H/V, D) is the horizontal (H) or vertical (V) NSE tolerance at distance D
D is the distance from threshold
TRSA is the expected horizontal (H) or vertical (V) accuracy, in meters, of the truth reference system at distance D

If the horizontal and vertical accuracy characteristics of the truth system are different, then the preceding equation is applied twice: once to generate the horizontal tolerance brackets, and once to generate the vertical tolerance brackets. It is recommended that the truth reference system used be capable of assessing the measured NSE against tolerances that are at least as stringent as those specified in Reference 2 for Category I ILS precision approach procedures (structure and alignment).

Horizontal (Vertical) Dilution of Precision Window: The horizontal (or vertical) dilution of precision window (vertical label HDOP in Figure 4) is used to present the HDOP data output by the WAAS Flight Inspection Receiver. These data are presented for informational and consistency purposes. Optionally, the expected HDOP (VDOP) data may be presented in this window, also. As with the expected HPL (VPL) data, the expected HDOP (VDOP) data may be useful in assessing interference effects. In addition, the information in this window may indicate the reason for out-of-tolerance NSE or HPL data.

Course Deviation Indicator Window: The course deviation indicator window (vertical label CDI in Figure 4) is used to present the CDI data. This data provides an indication of how well the procedure was flown. Depending on the linearity of the CDI indication (recorded sensor output), excessive flight technical error may result in inadvertently failing the waypoint displacement assessment. This situation is likely to result when the sensor CDI output scaling is “capped” or of lower resolution in the full-scale deflection region.

There are various ways to present the required data and analysis, and some suggestions are provided in this paragraph. The example flight inspection records shown in Figures 4 and 5 are intended to provide a reasonably detailed assessment of the approach procedure from a flight inspection perspective. Optionally, Figure 6 shows a more basic format that could be used for the approach maneuver. This format presents only the data necessary for making a pass/fail determination, and it presents the horizontal and vertical performance data on the same record. The formats shown in Figures 4 and 5 could be used for commissioning flight inspection missions, where a more thorough assessment of the procedure is desired. In addition, this format could be used to enable further assessment of the situation when the more basic format indicates an out-of-tolerance condition. The format shown in Figure 6 could be used for periodic flight inspection missions.

B. Below Procedure Maneuver

The below procedure maneuver involves flying straight-line segments with specified horizontal and vertical profiles. The below procedure maneuver is performed routinely along the procedure horizontal track (normally centerline extended) as described below:

- Horizontal track aligned with the approach procedure horizontal track (typically the runway centerline extended) and a vertical profile which clears all obstructions and is below the vertical course width region (full scale fly-up).

The data collected are analyzed in order to identify the presence of RF interference, a method for performing such an analysis is discussed in a subsequent paragraph of this section. If interference is suspected, then below procedure maneuvers are performed as described below:

- Horizontal track along the left course width limit (full scale left) and a vertical profile which clears all obstructions and is below the vertical course width region.

- Horizontal track along the right course width limit (full scale right) and a vertical profile which clears all obstructions and is below the vertical course width region.

Two of the four types of assessment are performed during the below procedure maneuver. The two assessments are: verifying the obstruction environment, and identifying the presence of RF interference. Part of assessing the presence of RF interference includes assuring that a full fly-up indication is provided below the approach procedure.

Figure 7 shows an example flight inspection record for the below procedure maneuver. This record consists of a header block and six data windows. One such record is generated for each below procedure maneuver performed. The header block and the MCNR, FLG, E/A HPL, and E/A VPL data windows are utilized in the same manner as discussed above for the approach procedure maneuver.

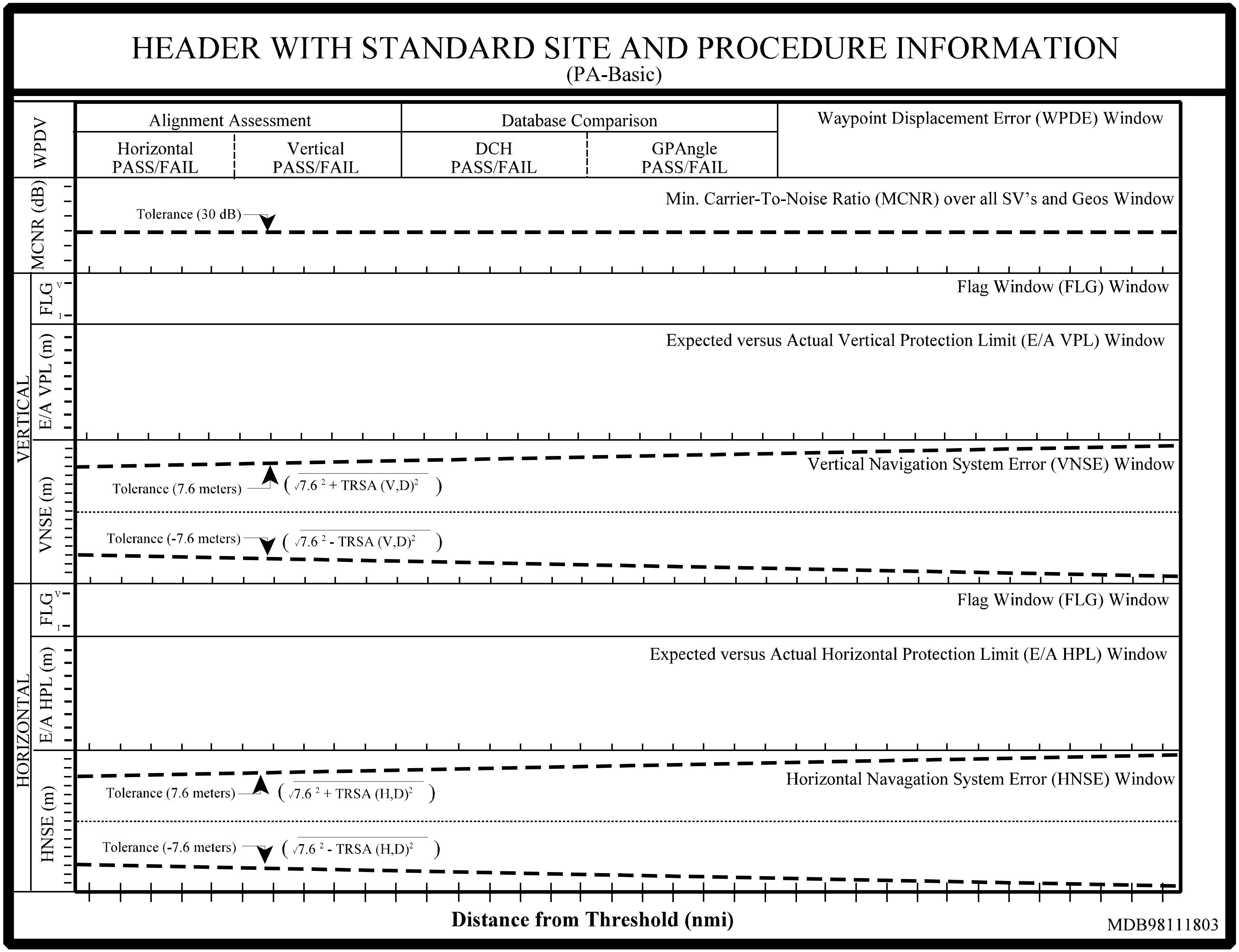

Figure 6. Example Record for the Approach Procedure Maneuver, Basic Format.

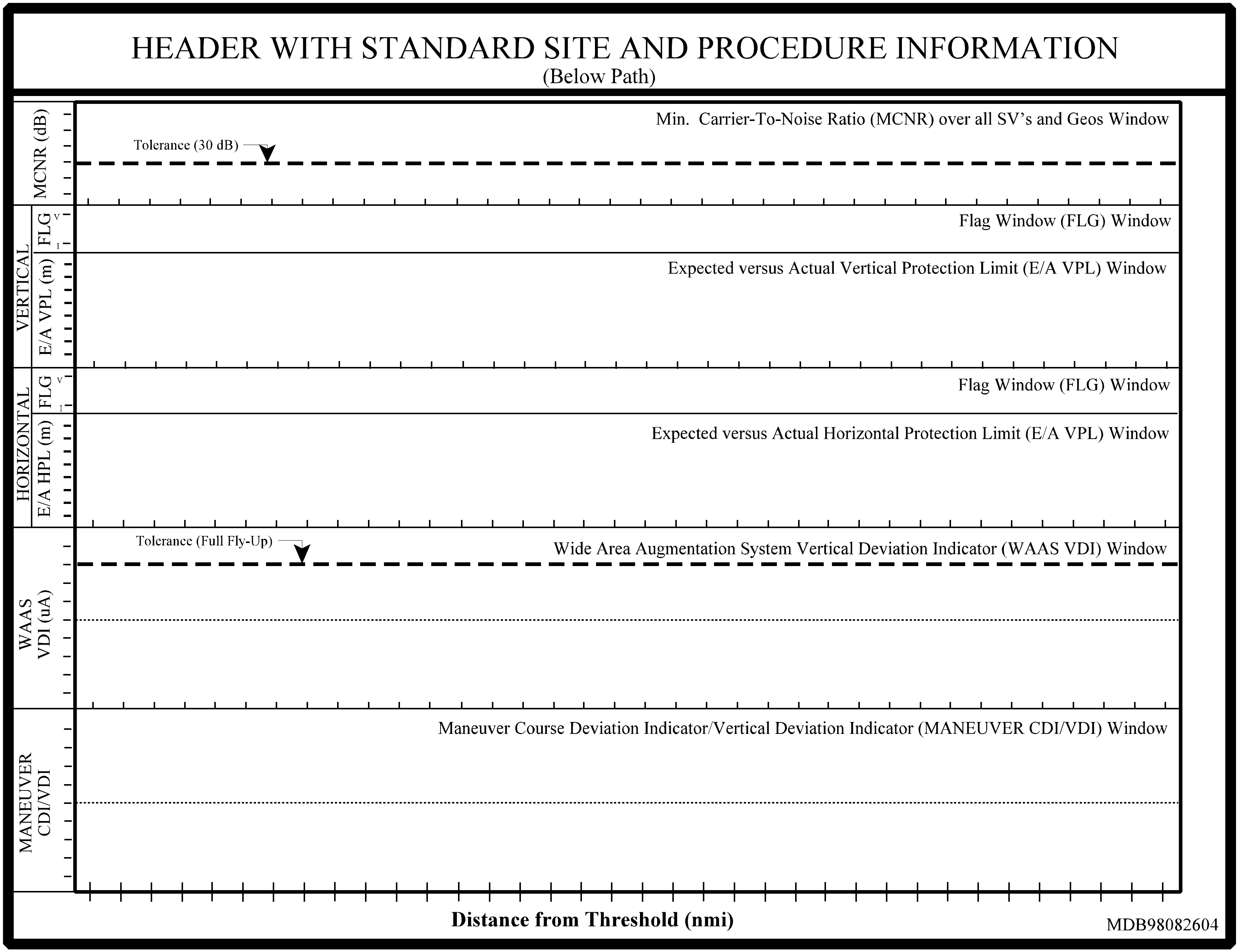

Figure 7. Example Record Format for the Below Procedure Maneuver.

Wide Area Augmentation System Vertical Deviation Indicator Window: The WAAS vertical deviation indicator window (vertical label WAAS VDI in Figure 7) is used to present the WAAS-based vertical-deviation indicator data for assessment during below procedure maneuvers. That is, the vertical-deviation data is provided by the WAAS flight-inspection receiver, which is using the published waypoint information.

Maneuver Course Deviation Indicator/Vertical Deviation Indicator Window: The maneuver course deviation indicator/vertical deviation indicator window (vertical label Maneuver CDI/VDI in Figure 7) is used to present the course/vertical deviation data (two data traces) corresponding to the particular below procedure maneuver. These data document how well the intended below procedure maneuver profile was flown. In this case, it is assumed that a separate guidance system/set-up is used to provide guidance information relative to the intended below procedure maneuver.

IV. DATA COLLECTION/REDUCTION REQUIREMENTS

The current WAAS receiver (modified Rockwell-Collins E-MAGR) is presently in the last stages of development and precise data formats and their content have not been finalized. As a result, the data collection requirements will be presented from a generic perspective: the data source will be identified but source specifics will be omitted. Complete details of the finalized WAAS receiver interface [7] should be available through NAWC/AD, Patuxent River, MD, Attention: Mr. Glen Colby.

There are three basic sources for flight inspection data: the Aircraft Flight Management System (FMS), the Automated Flight Inspection System (AFIS), and the WAAS receiver. Serial data, output at 76.8 kbps from the receiver, are expected to be available on the RS-422 instrumentation bus. It is assumed that ultimately all data elements from the receiver will be stored by the AFIS for subsequent retrieval--either during the actual flight-check event or at some later time. In order to be certain that the collection of data is properly initialized, no flight inspection event should be conducted until it is verified that all WAAS message types, with consistent Issue of Data (IOD) information, have been received and recorded. This will generally require a wait of from five up to a maximum of 20 minutes--20 minutes is the time-out interval for the Ionospheric Grid Mask information [5: A-61]. Verification of WAAS data shall be implemented within the WAAS receiver resulting in a go, no-go flag for the precision approach.

Appropriate data reduction algorithms shall be developed for the AFIS to support the flight inspection event(s). It is anticipated that data elements from the WAAS receiver and information from the aircraft flight management system, as well as some manually entered data, will be used to accomplish this task. The information available through data reduction, the so-called derived data, along with truth data supplied through the AFIS, will be used to generate the actual flight inspection records.

A. Essential Data Elements for Flight Inspection

1. Position (ecef or llh), velocity (m/s) and heading (rad) with time tags -- source: WAAS Receiver

2. CNR (dB/Hz) for all SVs (GPS and GEO) used in position solution with time tag -- source: WAAS Receiver

3. VDOP, HDOP (value) with time tag -- source: WAAS receiver

4. VPL_{WAAS}/HPL_{WAAS} (m) with time tag -- source: WAAS receiver

B. Auxiliary Data Elements for Diagnostic/Historical Usage

1. Pseudorange (m), CNR (dB/HZ), Carrier Phase (count), Ephemeris Data (record), Smoothed Pseudorange (m) for all SVs (GPS and GEO) tracked: all elements with applicable time tag -- source: WAAS receiver

2. WAAS message(s) with time tag -- source: GEO via WAAS receiver. From ICD information [7: Appendix D], this data should be available in decoded ("WAAS Type" message format) or in undecoded (raw data) form. A full complement of WAAS messages is received every 20 minutes (worst case). All WAAS information of this nature should be archived for later analysis (diagnostic or historical); thus, raw data are probably the best form to retain since all WAAS messages can be recovered therefrom.

C. Derived Data

1. HEADER BLOCK -- consistent with AFIS identification data and FAA requirements

2. Waypoint displacement error(s) (units consistent with HEADER BLOCK)

3. Minimum CNR (dB/Hz) of all SVs used in position solution versus distance from threshold (nmi)

4. Expected $\{HPL_{WAAS}/VPL_{WAAS}\}$ (m) versus distance from threshold

5. Horizontal Navigation Sensor Error (m) versus distance from threshold (nmi)

6. Expected {HDOP,VDOP} (value) versus distance from threshold (nmi)

7. CDI(μA)/FLG(discrete) versus distance from threshold (nmi)

8. Vertical Navigation Sensor Error (m) versus distance from threshold (nmi)

9. VDI(μA)/FLG(discrete) versus distance from threshold (nmi)

V. CONCLUSIONS AND RECOMMENDATIONS

Provisional flight inspection criteria have been developed for the inspection of the WAAS precision approach procedures. These criteria are intended to be applied to the Final Approach Segment; inspection of all other segments should be accomplished by using the applicable criteria for C129 procedures (need more formal reference).

The following recommendations are offered for consideration:

- Further work should be performed to assess the suitability of the tolerance proposed for the minimum carrier-to-noise ratio data. This work should review receiver performance and certification requirements, as well as the assumed WAAS interference mask to determine the suitability of the 30 dB/Hz tolerance that has been proposed.

- The operational acceptability of the waypoint displacement error tolerances proposed in Table 2 should be assessed by FAA certification personnel.

- Further work should be performed to determine an operationally suitable tolerance for the difference between the expected and actual horizontal/vertical protection limits. This work should consider employing analytical, simulation, and field measurements as means of establishing a suitable tolerance.

- The practicality of implementing the proposed criteria on a routine, day-to-day manner should be assessed. Flight trials should be performed to assess the feasibility of implementing these criteria, as well as identify implementational and efficiency issues.

VI. REFERENCES

1. Jeppesen Sanderson Inc., Federal Aviation Regulations/Aeronautical Information Manual 98, 1998.

2. Departments of the Army, the Navy, the Air Force, and, the Federal Aviation Administration, United States Standard Flight Inspection Manual 8200.1A Chg 2, August 1998.

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